MULTIFREQUENCY OBSERVATIONS OF THE GAMMA-RAY BLAZAR 3C 279 IN LOW-STATE DURING INTEGRAL AO-1

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ABSTRACT

We report first results of a multifrequency campaign from radio to hard X-ray energies of the prominent γ-ray blazar 3C 279 during the first year of the INTEGRAL mission. The variable blazar was found at a low activity level, but was detected by all participating instruments. Subsequently a multifrequency spectrum could be compiled. The individual measurements as well as the compiled multifrequency spectrum are presented. In addition, this 2003 broadband spectrum is compared to one measured in 1999 during a high activity period of 3C 279.

Key words: γ-rays: observations - galaxies: active - galaxies: quasars: invidual: 3C 279.

1. INTRODUCTION

The EGRET experiment aboard CGRO has identified about 90 blazar-type AGN emitting high-energy (>100 MeV) γ-rays (Hartman et al., 1999). Among the most prominent ones is 3C 279, an optically violently variable (OVV) quasar, located at a redshift of 0.538. It shows rapid variability in all wavelength bands, polarized emission in radio and optical, superluminal motion, and a compact radio core with a flat radio spectrum. These properties put the quasar 3C 279 into the blazar sub-class of AGN. According to the unified model of AGN, blazars are sources which expel jets close to our line-of-sight. The blazar emission is predominantly of non-thermal origin, showing a typical two-hump spectrum from radio to γ-rays. It is generally believed that in blazars the radio–through-optical/UV continuum is synchrotron radiation generated by relativistic electrons in a magnetized jet and the high-energy continuum from X-rays to γ-rays is due to Comptonization of soft photons by the non-thermal jet electrons. Most emission models have been developed within this scenario. Key predictions of the different models which can be tested by multifrequency observations are the predicted spectral shapes for blazars from radio to γ-ray energies, and the predicted temporal variations as function of energy.

3C 279 was detected by EGRET several times (e.g., Hartman et al., 2001), showing strong flaring activity with flux changes up to a factor of 100. 3C 279 was also detected by CGRO/COMPTEL at low-energy (1-30 MeV) γ-rays (e.g., Williams et al., 1995) and CGRO/OSSE (50 keV - 1 MeV) at the transition from hard X-rays to γ-rays (McNaron-Brown et al., 1995), i.e., throughout the whole INTEGRAL band and above. Because of the low-significance OSSE detections, which only occurred on or near flaring periods (McNaron-Brown et al., 1995), not much is known on the hard X-ray properties of 3C 279. To improve on that INTEGRAL observed the blazar in its AO-1 period. To correlate the hard X-ray and multifrequency properties of 3C 279, the INTEGRAL observations were supplemented by multifrequency coverage, i.e., contemporaneous radio and mm, near-infrared and optical observations, as well as X-ray observations.

In this paper we present first results of our multiwavelength campaign on 3C 279 in 2003 (not all data are available yet). Because of the limited page number, we concentrate on presenting the main observational results. A more detailed presentation, including a discussion on the scientific implications of the new results, will be given in a later paper (Collmar et al., in prep.).

2. OBSERVATIONS

3C 279 was observed continuously for 300 ksec in INTEGRAL AO-1 between June 1 and June 5, 2003. These high-energy observations were supplemented in X-rays by a short Chandra pointing of 5 ksec on June 2, and by ground based monitoring from radio to optical bands, including the following measurements: 37 GHz at the Metsähovi radio telescope, 250 GHz at the SEST, 3 mm, 2 mm, and 1.3 mm at the 30m IRAM telescope, optical R-band monitoring at the 60cm Tuorla telescope at La Palma, and UBVRI photometry at the 2.3m telescope at Siding Spring, Australia. In addition, VLBA observations at six radio frequencies from 5 to 86 GHz have been carried out and the resulting data is currently being reduced.

The data analysis revealed that 3C 279 was observed in a deep low-activity state. This is obvious from Fig. 1, which shows the longterm optical R-band light curve of the blazar during the last 10 years. According to CGRO experience, the optical R-band is a good tracer for the high-energy activity of blazars. The campaign was carried out during the faintest R-band brightness of the last 10 years, roughly 5 mag fainter than the maximum, and about 2.5 to 3 mag fainter than average.

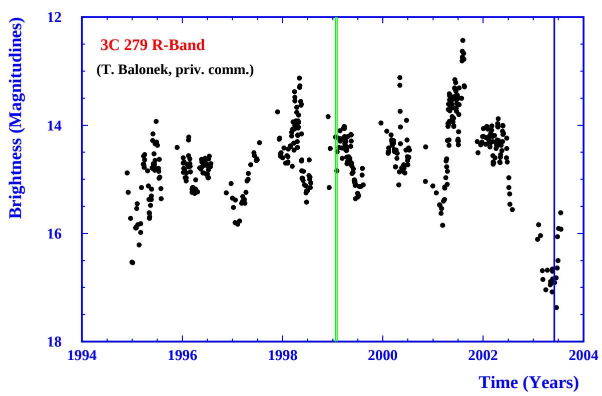


Figure 1. Longterm R-band light curve of 3C 279 during the last ten years. The right line indicates the observation time of INTEGRAL in 2003, and the left line corresponds to a γ-ray high state observation in 1999 (see section 3.3). The INTEGRAL observation was carried out during the lowest R-band flux state of the last 10 years. The figure is from Balonek (2004).

3. RESULTS

3.1. High-Energy Observations

The IBIS/ISGRI experiment aboard INTEGRAL detected the γ-ray blazar at energies between 20 and 80 keV with a formal significance of 6.6σ. Above 80 keV no signs of 3C 279 could be found yet in the IBIS data. The ISGRI spectrum between 20 and 80 keV, compiled in 6 spectral bins, is, by assuming a power-law shape, consistent with a photon index of 1.9±0.4 (1σ). INTEGRAL/SPI and -JEM-X analyses did not yet reveal a significant detection of the source, although marginal evidence is found in the JEM-X data. The ISGRI detection is, together with the CGRO/OSSE detection in 1991 (about 10σ in one 50-150 keV bin; McNaron-Brown et al. 1995) the only significant detection at hard X-rays. In particular, the spectral shape of 3C 279 could be measured in the 20 to $\sim$100 keV range for the first time, although the blazar was in low-activity state. Given this result, a hard X-ray spectrum of unprecedented quality for 3C 279 should be measured in a high-state observation for a similar observation time. The ISGRI image and spectrum are shown in Fig. 2.

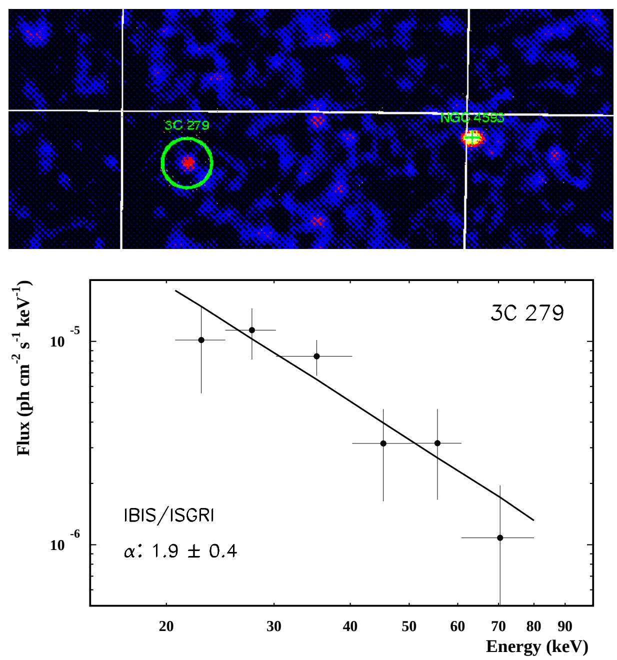


Figure 2. Top: The ISGRI image shows a 5.4σ detection of 3C 279 in its sensitive 30-50 keV band. In addition, the Seyfert galaxy NGC 4593 is even more clearly detected.
Bottom: The ISGRI hard X-ray spectrum between 20 and 80 keV is shown, together with the best-fit power-law shape.

The contemporaneous short Chandra pointing was carried out with the LETGS (Low Energy Transmission Grating Spectrograph). This setup was used to search for a possible soft excess. In fact, the goal was to measure the crossover point of the anticipated *low-energy* synchrotron and *high-energy* inverse-Compton emission by using the improved soft X-ray sensitivity of Chandra compared to previous X-ray missions. The energy of this crossover point is inferred to be at soft X-ray energies by modeling the 3C 279 broadband emission (e.g., Hartman et al., 2001), but has never been observed yet. The blazar is clearly visible in the 0th order of the LETGS, however, is weak in its 1st order, which is necessary to generate an energy spectrum. Therefore only a weakly determined spectrum between 0.2 and 6 keV could be derived. Assuming the canonical power-law shape at X-ray energies, spectral fitting yields a best-fit shape (Fig. 3) of photon index 2.1±0.3 (1σ). This value suggests a softer spectrum than usually measured in X-rays, however, is still consistent with the canonical X-ray power-law slope of photon index of $\sim$1.7. In particular, no soft excess is found in the data.

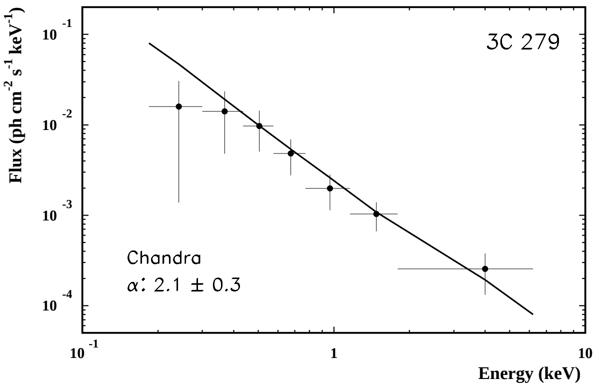


Figure 3. The Chandra 0.2 - 6 keV X-ray spectrum is shown, together with the best-fit power-law shape.

3.2. Low-Energy Observations

Because 3C 279 is a prominent blazar, it is monitored regularly in radio, IR and optical bands, probably at least on a monthly basis or so. However, during our campaign the monitoring was denser, and, in particular, was carried out contemporaneously in the different bands including large telsecopes (e.g., 2.3m Siding Spring telescope, 30m IRAM telescope) to derive accurate flux estimates. Some monitoring results are shown in Figs. 4 and 5. Generally, the results of the ground-based monitoring can be summarized as follows: 1) the flux of 3C 279 was surprisingly stable, and 2) the flux level was generally lower than average, especially in the optical bands.

3.3. Multiwavelength Results

Because the different measurements were collected contemporaneously (i.e., within the INTEGRAL observational period of 4 days), a multifrequency spectrum from the radio to the hard X-ray band could

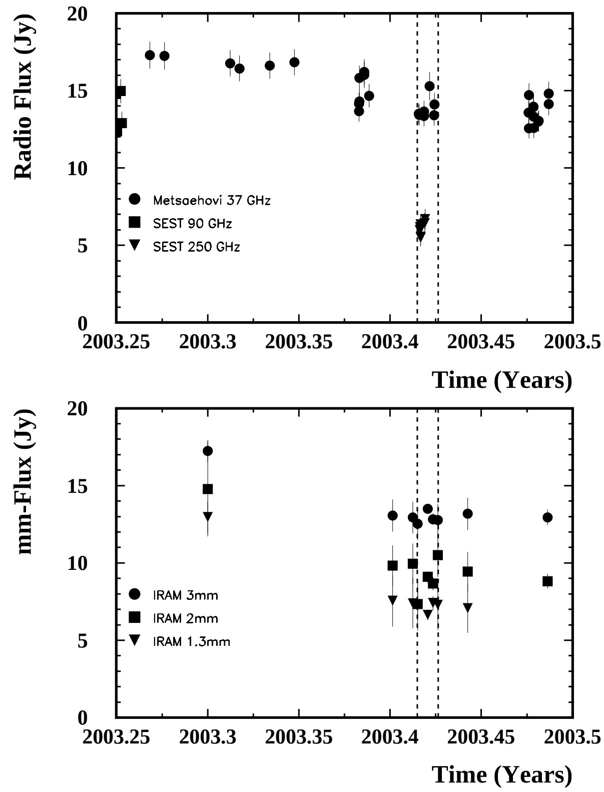


Figure 4. Radio and mm light curves from monitoring observations at or around the INTEGRAL observational period, which is indicated by the vertical dashed lines.

be compiled (Fig. 6, top). In case of serveral measurements during the INTEGRAL period (e.g., the IRAM mm measurements), the fluxes were averaged. This spectrum shows the typical two-hump shape, which is believed to be synchrotron at the lower - and inverse-Compton (IC) emission at the higher energies. The radio and mm fluxes are, as usual, on the rising branch of the synchrotron emission, whose actual maximum, probably located at IR energies, is not observed. The optical data points (UBVRI photometry at Siding Spring) are on the decaying branch of the synchrotron emission, showing almost a perfect power-law shape. The X-ray and hard X-ray fluxes are already on the rising IC branch of the emission. Because Chandra did not find a soft excess, the crossover point of the synchrotron and IC emission is not observed. Therefore it has to be lower than 0.2 keV. This low-state multifrequency spectrum generally resembles the one measured by Maraschi et al. (1994) during another low-state period of 3C 279 in December/January 1992/93, still including the CGRO experiments. However, by the participation of Chandra and INTEGRAL, the 2003 one is covered much better at X- and hard X-ray energies. A comparison of these 2 spectra will be scientifically interesting; the two spectra might even complement each other.

In Fig. 6 (bottom), the measured low-state is compared to a high-state measurement during the CGRO

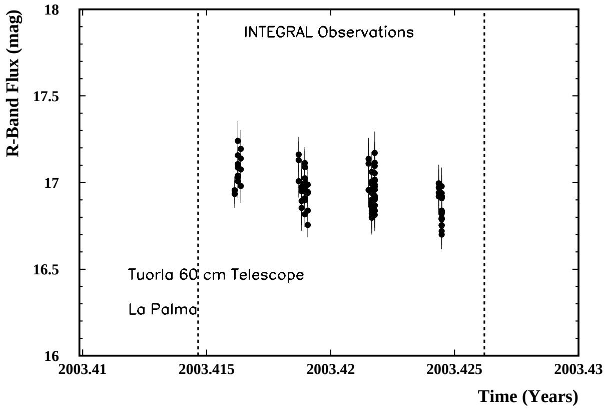
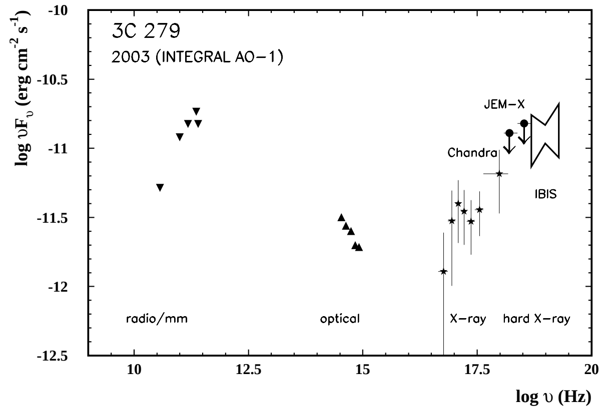


Figure 5. Daily R-band monitoring during the campaign by the Tuorla 60cm telescope. Noteable is the surprisingly steady flux during the 4-day period. The INTEGRAL observational period is indicated by the vertical dashed lines.

era in 1999 (Collmar et al., 2000). At radio and mm bands the fluxes are at the same level, though if comparable, lower than during the high-state observation. The main deficit occurs in the optical bands, where the flux is more than 1 order of magnitude below the high-state observation. At soft X-ray energies, not covered during the high state, the Chandra measurements indicate a deep minimum, located somewhere in the UV. Above 2 keV (covered by RXTE during the high state), the flux level approaches the high state one. The new and surprising fact is, that despite the large differences in optical flux, the hard X-ray flux, as measured by ISGRI, is quite close to the high-state measurement. The main deficit occurs from at least the optical to the X-ray band. Something happens which suppresses the synchrotron flux at optical energies but only weakly affects the SSC flux at hard X-rays. This result provides at least new constraints for the modelling of 3C 279.

4. SUMMARY

A multiwavelength campaign on the prominent and variable γ-ray blazar 3C 279, including INTEGRAL, was carried out in 2003. According to the longterm optical R-band lightcurve, the source was observed in its lowest optical activity state of the last decade. Because the source was detected by all participating instruments, a scientifically interesting low-state multifrequency spectrum could be compiled from radio to hard X-ray energies. It has an unprecedented coverage in the high-energy domain by Chandra and INTEGRAL, and provides new constraints for the modelling of 3C 279.



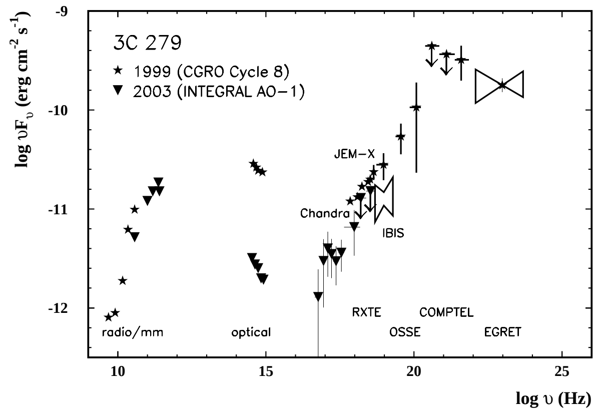


Figure 6. Top: The 3C 279 multifrequency spectrum as measured during the campaign in June 2003. The spectrum shows the typical two-hump shape, with a crossover between the optical U band and 0.2 keV. Flux points are shown with 1σ error bars. Upper limits are 2σ. For ISGRI the error contours on the spectral shape are given. The JEM-X upper limits correspond to the bands 5-10 keV and 10-20 keV. At low energies the error bars are smaller than the symbols.
Bottom: Comparison of the 2003 low-state spectrum to the high-state multiferquency spectrum of 1999 (Collmar et al. 2000). In particular, the optical fluxes are more than an order of magnitude different.

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